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THE SEARCH FOR SIGNALS OF EXTRATERRESTRIAL LIFE

by

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NOTICE

The search for signals of extraterrestrial life is connected with the general problem of existence and distribution of intelligent life in the Universe, which for a long time was a province of science fiction or at the most a province of speculative conclusions. However, recently it became an object of scientific research. More than that, a portion of the problem which relates to the forms of life on the planets of the solar system has already been partially resolved. On the basis of astronomical, radioastronomical, and direct experimental research, which was conducted by the Soviet station on Venus, it can be concluded that not only do civilizations not exist on the nearest planets of the solar system, but even the existence of simple forms of life there is questionable.

Therefore, one can speak only about search of signals from civilizations on planets near other stars of the Universe.

As a result of biological, chemical, and astronomical research, a conviction has emerged that the living and intelligent matter is not an accidental or a rare phenomenon, but is an absolutely necessary consequence of its evolution. It is true that paths of the evolution are not completely clear, however we cannot consider the intelligent life on Earth as a single and only phenomenon, not only in the Universe, but also in the modest spacial extensiveness of our Galaxy, which consists of only 10^{11} stars. In the observable portion of the Universe, there are still approximately 10^{10} Galaxies similar to ours.

Therefore, the human aspiration to discover an intelligent life in other worlds can be easily understood. To a considerable degree the solution of this problem lies in the search of the signals from other civilizations and in establishment of a contact with them. At the present time this problem is transferred from the region of theory into the region of practical realization; many books by foreign and our own authors are devoted to this problem. Above all the origin of the interest toward this problem is connected with the achievements in the field of reception and transmission of electromagnetic signals. We are now in possession of radiophysics and radioastronomy which allows assurance of cosmically distant contacts.

However, before considering the question of how such contacts are to be achieved, it is necessary, even if in only few words, to explain and appraise the distribution of the intelligent life in the Universe.

DISTRIBUTION OF INTELLIGENT LIFE

The view on the degree of the distribution of intelligent life has changed according to the degree of development of science. This is connected with our knowledge about the evolution of stars and planets. Achievements of astrophysics in the last two decades allow approaching the solution of the problem from a scientific point of view.

The issue in the appraisal of distribution of the intelligent life is the interval of time from the origin of the planet to the development of civilization which realized the possibility of establishing a contact and which has this opportunity. For the Earth, this time is approximately $3\text{-}4\cdot10^9$ years.

Therefore, we can be interested only in the stars of approximately such age. It is said, that such requirements are met mostly by stars of spectral class F, G, K. The sun belongs to the class G.

But do all stars have planets? Earlier it was considered, that the origin of a planet is connect with a collision of stars. However, this phenomenon is hardly probable. At the present time the widespread opinion is that the origin of planets is simultaneous with the origin of stars. The origin of a planetary system of a star is, in fact, a very necessary stage of the evolution. Therefore, it is very probable that planets exist with almost each of the stars.

The proof to this is multiple. In reality, almost one half of all stars are double and even triple stars which revolve in a relationship to one another. It is quite sensible to consider, therefore, that there is an uninterrupted transfer of masses of weaker components of double stars to the masses of their planets.

It is important, that the stars of the classes F, G, K sharply decrease their own rotation as compared with the other classes. This can also be explained by the presence of planets which take up a portion of the momentum of rotation. And, finally, recently planetlike satellites were discovered near six of the 100 stars nearest to the Sun. These stars are experiencing a periodic displacement, which can only be caused by perturbation from the satellite of the star, in other words, from the planet or a group of planets.

Stars of the classes so far considered, each of which can have planetary systems, make up about one half of all stars.

Further, it is necessary for us to know the share of stars, planets of which fall into the so-called "life zone" of the star. This zone, where the energy of the star is sufficient for the origin on that planet of normal temperature conditions of the existence of living matter in an earthly, that is an albumen realization. But even this is not all. It

is necessary for these planets to have an atmosphere and other conditions. The analysis, which were conducted by scientists, had shown that on not all planets in the zone of habitation can the conditions analogous to that of our Earth exist. For example, in order for the planet to hold its atmosphere the radius of the planet, depending on the density of the matter, must be more than 2000 km.

At last, the very essence in the appraisal of the distribution of intelligent life is the duration of existence of a technically developed civilization. The analogy with the Earth, in this case, is but of very little help because our age as a technically developed civilization cannot be said to be more than 50 years.

Some scientists determine a life of a civilization as being equal to 10,000 years. Let us be optimists and suggest that a technically developed civilization is able to exist 1,000,000 years.

The number of stars N near which there is intelligent life, out of a total number $N_з$ can be computed according to the formula:

$$\frac{N}{N_з} \simeq \frac{T_ц}{10^{10}} \simeq 10^{-6} - 10^{-4},$$

where $T_ц = 10^4$-10^6 years--the duration of the life of a civilization which is able to communicate.

As it is seen from the correlation, in the first case, a Galaxy can have in all 10^5 stars, and in the second--10^7 stars on which civilizations are possible.

From the frequency of civilizations it is easy now to shift to the appraisal of average distance between them. It so happens, that the average distance between civilizations consists of 70-700 light years. This is the distance onto which our research should be distributively concentrated.

In the radius of the 100 light years from our Sun, there are located about 10^4 stars, but in the radius of 1,000 light years--10^7 stars are located.

THE POSSIBLE METHODS OF ESTABLISHING CONTACTS

At the present time the following kinds of contacts could be thought of as possible: 1) The interplanetary manned flights; 2) The unmanned flights by automatic zonds to the other stars; 3) Discovery and exchange of signals of electromagnetic radiation. Other possibilities are not yet known to us.

According to the opinion of the majority of specialists in the field who have made corresponding calculations, the first and second methods of establishing contacts cannot be achieved by the science of today, but appear fantastically impossible even from the point of view of a distant future in the development of science and technique.

And at the same time the field of rocketry is quite effective in the research of our solar system. Rocketry will undoubtedly become the distributive media of mankind throughout the solar system, a period of assimilation of which is appraised at 10,000 years. Moreover, the field of rocketry will become the media of gradual expansion of our civilization into the neighboring solar systems. This process, which is similar to diffusion, over periods of tens of millions of years can lead to population of a considerable portion of our Galaxy.

In connection with assimilation of the solar system the reasoning of Dayson is interesting. He points out, that the population explosion on our planet or for that matter of any other civilization will unescapably lead to the aspiration of more complete utilization of that which flows from the star (Sun). As a result the star can be surrounded by some kind of artificial celestial sphere where the civilization will settle, utilizing in this way, 100% of the radiant energy of its own star. Trapping the light radiation of its own star, the Dayson sphere, as it is called, will reradiate energy as an infrared radiation into the space. The temperature of the radiation will be about 300 K, and the maximum of the reradiated energy will fall into the wave region of 10-15 micron. For the earthly observer such a system will appear as a large star which radiates only infrared waves.

Not long ago Dayson published a work in which he researched the methods and the construction of the sphere in detail.

The single realistic possibility of establishing contacts with civilizations of other planets remaining is the electromagnetic communication. According to the idea, which for the first time was expressed by Cocconi and Morrisson in 1960, this communication must be carried out on the wave of 21 cm.

Let us consider the optimal range of waves for such communication. For the long waves the range is limited by the transparency of the ionosphere. However, these are not the principal limitations, as it will be possible in the future to penetrate beyond the atmosphere and the ionosphere. The principal limitations are caused by the specific noises of the background of cosmic radioradiation. Practically, this background makes the reception and transmission of the information on the waves longer than 50-70 cm unreasonable. The range of the short wave purity is limited by its very own quantum noises of the apparatus.

With respect to the atmospheric absorption, this limit is presently located somewhere near the wave of 4-10mm. In this range are waves which are isolated by their very nature and are known to all civilizations--that is the radiation of the neutral hydrogen on the wave of 21cm and the hydroxyl on the wave of 18cm.

For the contact signal or the signal beacon, the purpose of which will be to attract attention, these waves will be most suitable. However, because of the Doppler effect as a consequence of the relative motion of the corresponding stars and planets, the purity of the reception may be dislocated. According to the appraisal, this dislocation will not go beyond the line of 1 Mg. cycle near the selected purity.

Concerning the utilization of the laser beam radiation, the analysis conducted by Townson, Schwartz, Oliver and others show that the achievable distances with the aid of the laser are of a lesser magnitude than those which can be achieved in the radiorange. This is primarily caused by insufficient power of the lasers, and secondarily, by the interfering radiation activity of the star.

The radiation of the laser from a planet of a distant star cannot be distinguished from the radiation of the star itself, since their angular distance of separation will be so insignificant that it will hardly lend itself to the resolution of differentiation by the telescopes of today. For example, the radiation of the laser on the Earth, which is being observed from a distance of 3 light years, will stand apart from the image of the sun (which will appear in a shape of a dot) on an angle of only 1" of the arc. This is the limit of the resolution which is being stipulated by the influence of the Earth's atmosphere. The largest telescope in the world has the resolution of approximately 0.5". Consequently, the laser beam will merge itself with the light of the star and its isolation will be extremely difficult. Therefore, it was suggested that radiation should be of such a purity that it would fall into one of the Fraunhofer lines of absorption of the starlight, for example, hydrogen H_α lines, lines of calcium and others. Besides the obvious advantage in the relationship of signal to the noise, this method forms the accepted spectrum sharply different from the usual spectrums of star absorption, and the manipulation of the intensity of the laser would allow a definite conclusion about the artificiality of the signal.

Let us note that reception of the radiowaves will likewise be conducted in the background of ternal radioradiation of the star. However, the spectral intensity of radiation of stars in the radiorange is many magnitudes less than the radiation in the observable light.

THE ENERGETICS PROBLEMS

The question of transmission of signals into great distances which would correspond to the dimensions of the observable portion of the Universe, radius of which is approximately 10^{10} of light years--is, before all, a question of possession of sufficient energy. In connection with this, the reasoning of Soviet astronomers I. S. Shklovskiy and N. S. Kardashov is interesting.

The power capacity of the continuous world production of energy in our days is $3 \cdot 10^{12}$ volt. If one is to assume, that the yearly growth of this quantity will consist of only 1% (instead of 3-4%, which is the annual growth for the last 40 years) then in 3,000 years the capacity of energy production will consist of $4 \cdot 10^{26}$ volts, in other words, it will be equal to the total output of the Sun's radiation, and in 5,800 years at the same rate of growth it will reach the output of energy equal to the output of the whole Galaxy. From this then follows that if there are civilizations

in the Universe, then many of them, if not the majority, have reached the level of development which is characterized by the assimilation and serious transformation of their own planetary systems, linear dimensions of which can perhaps reach the dimensions of the Earth's orbit.

In correspondence with achieved stages of production of energy, N. S. Kardashov breaks technologically developed civilizations into three types: the first of the contemporary level of our Earth, the second is characterized by production and consumption of energy 10^{26} volts, that is of the magnitude of radiation of the star, and the third--the capacity of possession of energy of magnitude of 10^{26} volts. It is not difficult to compute that in undirected transmission in order to create a signal which would reach a distance of 10^9 light years, a signal sufficiently strong for reception by the contemporary media with the reception antenna $A = 10{,}000\ м^2$, temperature of noise of the receiver $T_ш = 10°K$, line of reception $\Delta f = 10$ gc, and the rate of transmission of not more than 10 double symbols per second in presence of a signal, which would exceed the noise by 10 times, the power capacity of the receiver of 10^{26} volts is required. This is exactly the capacity possessed by a civilization of the second type which has assimilated the energy of their own star.

As we have seen, the time needed for the origin of the civilization of the second type consists of 3-4 billions of years; at the same time, the transition from the first to the second type will require only several thousand years. Since the age of galaxies of the Universe is approximately 10 billion years, then it can be expected that each of the galaxies is in possession of a multitude of civilizations of the second type, and perhaps even civilizations of the third type.

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13. ABSTRACT

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